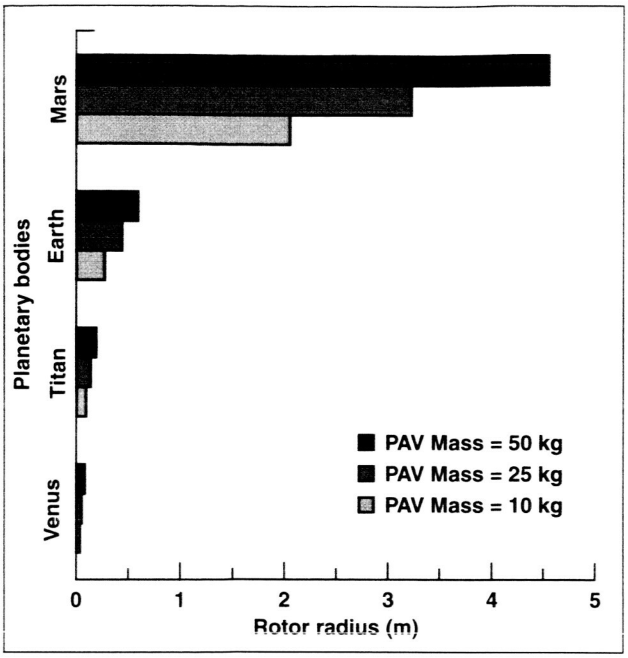

Fig. 1. Comparison of rotors sized for hover (for equivalent values of tip Mach number, solidity, and mean lift coefficient).

5. They would provide greater range, speed, and access to hazardous terrain than a surface rover.

6. They would provide greater resolution of surface details or observation of atmospheric phenomena than an orbiter.

The objective of the work being performed is to assess the feasibility of developing vertical-lift planetary aerial vehicles. Work to date has focussed on a conceptual design study of a Martian Autonomous Rotorcraft for Science (MARS). Given the thin, carbon-dioxide-based Martian atmosphere, developing a rotorcraft that can fly in that planetary environment will be very challenging. A university grant has been initiated to develop a conceptual design of a mission and flight-control computer architecture.

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Ballistic Range Tests Verify Stability of a Loaf-Shaped Entry Vehicle

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An entry vehicle whose shape resembles that of a loaf of bread has been proposed for missions to be flown as secondary payloads on the Ariane V launch vehicle. This shape conforms well within the volume available inside the Ariane structure for auxiliary payloads, and provides a much more efficient and larger internal packaging capability for the given launch-vehicle constraints than the conventional sphere-cone geometry (such as that of the Mars-Pathfinder entry vehicle). Because aerodynamic stability for this new class of vehicles must be evaluated, initial ballistic range testing was conducted to assess the supersonic behavior of loaf-shape vehicles. Figure 1 shows a shadowgraph image of the ballistic range model flying at supersonic speeds.

The loaf-shaped model for the ballistic range tests is sized to be launched from a 1.75-inch-bore gun. The model has geometry and mass properties that are similar to those being considered for the mission. Model dimensions are 1.15 x 0.78 x 0.66 inches and

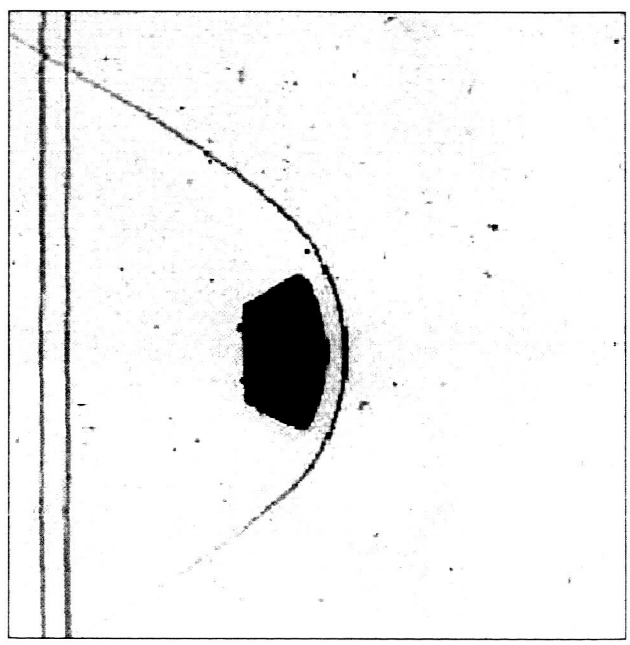

Fig. 1. Sample shadowgraph from aeroballistic testing of loaf-shaped entry vehicle.

the center of gravity is at 39% of the length (measured from the nose). An ambient density of 0.18 kilogram per cubic meter of carbon dioxide (CO_2) is chosen so that the Reynolds number will be consistent with that for the full-scale entry body at Mars. A nominal launch velocity of 680 meters per second ensures Mach numbers ranging from 2.5 down to 2 as the model decelerates along the length of the test section.

Four tests were conducted at consistent conditions in order to reduce uncertainty in the estimated aerodynamic parameters. The results summarized in Table 1 confirm the stable behavior of the loaf-shaped vehicle. The experimental value of drag coefficient is lower than the computational fluid dynamic (CFD) estimate because it includes wake effects. Pitch and yaw coefficients also indicate a discrepancy that is up to 20% of the CFD estimate, which confirms that analysis of the forebody alone does not adequately predict aerodynamic behavior at low supersonic speeds. Uncertainty in lift coefficient is relatively high because the angle-of-attack variation was small in some tests.

Table 1. Aerodynamic parameters of bread-loaf geometry in supersonic speed range.

Parameter	Forebody CFD estimate	Ballistic range estimate
CD_0	1.6	1.381 ± 0.002
Cm_α	-0.208	-0.18 ± 0.01
Cn_ß	-0.235	-0.28 ± 0.02
CL_α	-1.07	-0.80 ± 0.19

The results of this study indicate the feasibility of using a loaf-shaped entry vehicle which maximizes packaging capability for the Ariane V launch vehicle. If this shape is selected for future missions, additional tests and full-body CFD analysis should be performed to model the detailed flow more accurately and to reliably define the vehicle aerodynamic coefficients.

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Aerothermal Analysis of X-33 Elevon Control Surface Deflection

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As the X-33 nears final construction, the analytical emphasis has been redirected from generating design data to mitigating flight risk. Computational simulation of the flow field surrounding deflected elevon control surfaces has been performed to verify engineering estimates of the heating levels that the canted fin must be designed to withstand. This analysis serves to reaffirm design assumptions and reduce uncertainty, thus decreasing flight risk.

In previous simulations, surface heating predictions were based on the assumption of a smooth body. In reality, the body surface has both protuberances, such as steps and gaps formed between seals or tiles, and control-surface deflections that divert the flow from its nominal path. These surface irregularities and control-surface deflections trigger local fluid mechanical interactions that increase the heat transfer in some zone of influence on the surface. The thermal protection system is designed to account for these local effects by applying multiplicative scale factors, derived through empiricism and theory that augment the baseline smooth-body heating levels.

To validate the design correlations, computational fluid dynamics (CFD) techniques have been used to simulate the flow field around deflected elevon control surfaces. The geometric model includes the gap between the elevon control surface and the main body, the gap between the elevon surfaces, and the abbreviated edge of the elevon at the tip of the canted fin. Figure 1 shows radiative equilibrium surface temperature contours on the windward side of the X-33, along with an expanded view of the deflected elevon surfaces. The flow conditions are Mach 10, an angle of attack of 30 degrees, an altitude of 180,000 feet, and elevon control-surface deflection of 25 degrees. Evident in the figure is the increased heating on the face of the elevon generated by its deflection into the hypersonic flow field. Also discernible is increased heating on the sides of the elevon caused by the flow accelerating around the edges of the control surface. The maximum elevon surface temperature occurs in the gap region. These results are being used to verify the suitability of the design.